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13. ABSTRACT (Maximum 200 words)

Recent evidence indicates that the early stages in visual processing may be broken into several parallel streams that are specialized for the analysis of different visual attributes. A contour localization task showed that all attributes can contribute equally to border localization — no particular attribute dominated position decisions. The position decision appeared to be determined in a common representation. In contrast to this common analysis, a study of visual persistence showed that motion-defined shapes have a visual persistence which lasts longer than, and appears to be independent of, the persistence for luminance-defined shapes. Because of the involvement of motion, the site of the persistence phenomenon must be cortical. A series of experiments on transparency perception showed that transparency is analyzed rapidly (within 60 msec) and influences early levels of visual processing. We have also investigated the early stages that lead from the initial 2-D representation to object recognition. Visual priming studies have been completed which suggest that object recognition begins, not with the construction of a 3-D model, but with a crude match of 2-D views to internal prototypes. The prototype that has the best match then guides the construction of an internal 3-D model.

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Cooperativity and 3-D Representation

Objectives

Our work has concentrated first on how 2-D information is built up from the parallel analysis of a set of visual attributes and how this information contacts memory in order to construct 3-D representations of the visual scene. In addition, we are examining the analysis of overlapping surfaces when one of them is transparent. The resulting 3D representation includes two or more values of surface properties that are superimposed.

Progress Report

Cross-media cooperation in contour localization. This is Josée Rivest's thesis research and the experiments are completed and the thesis is ready to be submitted. She has been able to show that when discontinuities that are defined in several attributes are superimposed, the precision of vernier alignment improves as a function of the square root of the number of attributes combined. She has demonstrated that this is different from the improvement predicted by probability summation. This work was presented at ARVO in 1991. The last set of experiments measures the interactions between contours defined by different attributes. The results have challenged the models of Gregory and Grossberg that predict that luminance is a priviledged signal for contours and that other attributes fill out to the luminance-defined contours. For example, Josée finds that a color contour strongly attracts an adjacent luminance contour, displacing its perceived position towards the color contour. The contour representation appears to combine activity from several attributes. This work was presented at ARVO in 1992 and manuscripts are being prepared for publication.

Early visual memory: persistence. This work with Dr. Satoshi Shioiri, now a professor at Chiba University, Japan, has been completed and a report has just appeared in Vision Research. The results showed that a pattern created by moving dots persists after the motion stops providing a brief memory of the motion-defined shape. The duration of the persistence was about twice as long as that for luminance-defined patterns.

Transparency. Takeo Watanabe has made remarkable progress with this project. He has analyzed several aspects of transparency and illusory contours. He has 7 articles in print or in press resulting from work during the past granting period. In his most recent article he shows that transparency interacts with the McCollough effect, demonstrating that transparency influences processing even at fairly early levels. He also has a review article with me on transparency for a special issue of *Spatial Vision.* This will summarize his first four articles. Finally, he has developed a very promising new concept of "implicit X junctions" which he presented at ARVO this year. X junctions are the basic cue to transparency as one contour runs through another. In some physical conditions of transparency, the luminance on both sides of one arm of the X can be identical so that it is not visible. The junction is physically a T, the basic cue to occlusion. But the visual system discounts this in some instances and accepts a transparent interpretation. This also leads to a subjective contour in the transparent region, completing the implicit X. He is extending this idea to cover other subjective contour phenomena involving transparency such as the neon color spreading effect.

Object recognition: priming. This project is off the ground with Takeo Watanabe. A preliminary note of the theory was published last fall and early data are now

available. The idea is that recognition starts with an initial, crude 2-D match that selects a "best" prototype to explain the image data. This is followed by more sophisticated 3-D analyses to complete the recognition process. In the experiment, observers have to classify an image as a positive or negative (contrast reversed) image. Shortly before the image is presented, the contour alone is presented for a short interval. The contour is common to both the positive and negative tests and so gives no information whatsoever concerning the final response. It may, however, initiate or prime some early recognition processes such as the crude 2-D match and may therefore facilitate the response for the positive (but not the negative) image that arrives shortly thereafter. The experiment is now based on a set of 100 hundred faces and results are in for 10 observers. They do show a large RT difference between the positive and negative tests when the priming contour precedes the full image by at least 70 msec. The effect appears to be very large, the positive RT is more than 100 msec faster than the negative RT. For shorter priming durations, the advantage is reduced, dropping to 0 msec when the priming contour is not presented. Although the positive and negative tests are excellent controls for alternate explanations (masking, uncertainty reduction), we have just started further controls to verify that the effect is specific to recognition (using different subsets of the contours, some less informative than others). We would also like to use filtered image primes as well. Overall, if our results hold up, this project will be an important step forward in getting recognition processes into our experimental grasp.

Object recognition: visual search. Satoru Suzuki and I conducted two experiments to examine whether facial expression could serve as a feature in visual search. The work was presented at ARVO this year. In the first experiment, the target was a smiling face (middle) with frowning faces as distractors. Two types of frowning faces (F1 or F2) were used as distractors but only one type was presented on any given trial. The target and the F1 distractors differed both in expression and in the curvature of a single feature (the mouth) so that this task could be mediated either by facial expression or by a simple feature difference. On the other hand, no single feature distinguished the target from the F2 distractors since upward curving and downward curving arcs were present in both. Despite these differences, search was uniformly fast with both distractor types (64 and 63 msec/item, respectively), suggesting that it was the difference in expression that was the determining factor. In the second experiment, the identical features were rearranged to create equivalent non-face patterns (Fig. 2). A simple feature again distinguished the target from the N1 distractors but now no global feature was available. With the N2 distractors, no single feature could be used to perform the task and no global feature was present either. The performance with the two types of distractors now differed greatly (46 and 94 msec/item, respectively) showing that in the absence of facial organization, the curvature features do play an important role. These results demonstrate that facial expression is an emergent feature which can facilitate visual search in a difficult condition (F2 versus N2). An unexpected result was that the facial context also slowed performance (F1 vs N1) implying that the presence of the facial organization triggered a facial-feature analysis (smile amidst frowns) rather than the faster simple-feature analysis (target contained the only downward curving arc).

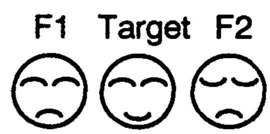

Fig. 1

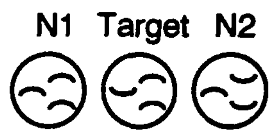

Fig. 2

Publications during grant period (* indicates support from grant)

Cavanagh, P, Adelson, E. H., & Heard, P. (1992). Vision with equiluminant colour contrast: 2. A large-scale technique and observations. *Perception*, in press.

Jolicoeur, P., & Cavanagh, P. (1992). Mental rotation, physical rotation, and surface media. *Journal of Experimental Psychology: Human Perception and Performance*, in press.

* Shioiri, S., & Cavanagh, P. (1992). Visual persistence of figures defined by relative motion. *Vision Research*, in press.
* Takeichi, T., Watanabe, T., & Shimojo, S. (1992). Illusory occluding contours and surface formation by depth propagation. *Perception*, **21**, in press.
* Takeichi, T., Shimojo, S., & Watanabe, T. (1992). Neon flank and illusory contour: interaction between the two processes leads to color filling-in. *Perception*, **21**, in press.
* Watanabe, T., & Cavanagh, P. (1992). Depth capture and transparency of regions bounded by illusory, chromatic, and texture contours. *Vision Research*, **32**, 527-532.
* Watanabe, T., & Cavanagh, P. (1992). Effect of duration on subjective transparency using the pattern identification task. *Perception*, in press.
* Watanabe, T., & Cavanagh, P. (1992). McCollough effect and subjective transparency. *Perception & Psychophysics*, in press.
* Watanabe, T., & Cavanagh, P. (1992). Surface decomposition in subjective transparency. *Spatial Vision* in press.

Bruck, M., Cavanagh, P., & Ceci, S. J. (1991). Fortysomething: Recognizing faces at one's 25th reunion. *Memory & Cognition*, **19**, 221-228.

Cavanagh, P. (1991). Short-range vs long-range motion: not a valid distinction. *Spatial Vision*, **5**, 303-309.

Cavanagh, P. (1991). The contribution of color to motion. In A. Valberg and B. B. Lee (eds.) *From pigments to perception.* New York: Plenum, 151-164.

* Cavanagh, P. (1991). What's up in top-down processing? In A. Gorea (ed.) *Representations of Vision: Trends and Tacit Assumptions in Vision Research*, Cambridge, UK: Cambridge University Press, 295-304.

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Cavanagh, P., & Anstis, S. M. (1991). The contribution of color to motion in normal and color-deficient observers *Vision Research*, **31**, 2109-2148.

Tyler, C. W., & Cavanagh, P. (1991). Purely chromatic perception of motion in depth: Two eyes as sensitive as one. *Perception & Psychophysics*, **49**, 53-61.

* Watanabe, T., & Cavanagh, P. (1991). Texture and motion spreading, the aperture problem, and transparency. *Perception & Psychophysics*, 50, 459-464.

Participating Professionals

Personnel on the grant this past year were myself (80% summer salary), Takeo Watanabe (Research Associate), Josée Rivest (graduate student research assistant) and Satoru Suzuki (graduate student summer research assistant). Josée Rivest has left to take a position as assistant professor at York University in Toronto and will defend her thesis in September. Satoru Suzuki will start as a graduate research assistant this summer. Takeo Watanabe has accepted a position as Associate Professor at State University of Arizona West and will leave in August. He will be replaced by Ron Rensink who has accepted a post-doctoral position here starting in September.

Interactions, papers during grant period (* indicates support from grant)

* Cavanagh, P. (1992). What are the orthogonal dimensions of vision. Dissection vision with perceptual studies in normals. Paper presented to the CVS Symposium on Localizing Visual Function in the Brain, Rochester, June.

Intriligator, J., & Cavanagh, P. (1992). An object-specific attentional facilitation that does not spread to adjacent locations. *Investigative Ophthalmology and Visual Science*, **33**, 1263.

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* Suzuki, S., & Cavanagh, P. (1992). Facial expression as an emergent feature in visual search. *Investigative Ophthalmology and Visual Science*, **33**, 1355.

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Charles, E., Logothetis, N. K., & Cavanagh, P. (1991) The response of cells in area MT to stimulation of blue-sensitive cones. *Society for Neuroscience Abstracts*, **17**, 440.

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